HARVEST AID FOR NARROW-INCLINED TRELLISED CANOPIES

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ABSTRACT. *A mechanical harvest aid was developed for narrow inclined trellises that allowed pickers free movement in order to optimize their picking time. The harvest aid featured auto-steer, continuous "creep" ground speed, a fruit sorting section, and automated bin filling. Field tests demonstrated the potential to improve worker productivity up to 22%, and effectively remove culls in the orchard. Fruit damage was unacceptable and will require refinements in the bin filler.*

Keywords. *Harvest, apples, pears, labor, mechanization.*

INTRODUCTION

The availability and costs of a skilled workforce to harvest and grade fruit is a major concern of the U. S. fruit industry (Hansen, 2004a; Morgan, 2002). The gradual tightening of labor supplies led to shortages in recent years and is expected to worsen in the future (Warner, 2003). Competition from countries with significantly lower labor costs will also force U. S. producers to reduce cost or lose valuable markets (Foster, 2004).

Hand-harvesting the U. S. apple and pear crop is labor intensive, requiring an average of 125 hours/hectare (50 hours/acre) (Brown it al., 1983). Considerable effort has been made by both researchers (Berlage et al., 1972; O'Brien and Berlage, 1983) and commercial companies (Anonymous, 1981; Klassen, 1987) to develop picking aids that position workers on machines to improve hand-harvest efficiency and reduce worker stress. Commercial harvest aids have been available in Europe for more than twenty years. Machines have had multiple sites for workers on the ground, or at elevated stationary or movable positions to locate the picker near the fruiting canopy. After picking, the fruit is usually placed on a conveyor system and transported to a bin filler. These machines have not substantially improved worker productivity and have not been widely adopted in the U. S. Reasons cited for the lack of productivity include: 1) non-uniform fruiting in the canopy which caused pickers to be idle; 2) unproductive time with picker positioning; and 3) picking rate limited by the slowest worker. Peterson et al., 1997 described a picking aid concept for narrow-inclined trellises that increased worker productivity up to 44% over conventional hand harvesting while maintaining the quality usually associated with careful hand picking. In an economical evaluation of this apple picking aid for inclined trellised canopy Peterson (1999) concluded that a three-worker picking aid operated for 12 weeks with workers picking at 8.2 kg/worker-min (18 lbs/worker-min) came close to being a breakeven situation with conventional hand harvesting. If a financial breakeven situation between the picking aid and hand harvesting exist, the picking aid may be beneficial to the tree fruit industry since the picking aid would reduce the number of labors require to harvest the crop. Commercial trials of this concept were never conducted.

It has been estimated that 15 to 20% of harvested tree fruit in bins are rejected as culls during packing (Hansen, 2004b). Transporting, storing, grading and sorting, and disposal of these culls are substantial costs to the growers and could be minimized if defective fruits were left in the orchard.

OBJECTIVE

The objective is to develop a picking aid for fresh market quality apples and pears, grown on narrow inclined trellises, that would maintain hand picked fruit quality, improve picker productivity, and permit in-field sorting so that only premium fruits are placed in the bins.

MACHINE DESIGN

A one-piece self-propelled experimental picking aid was developed to operate under the typical "A" frame trellis that many hectares of apples and pears are grown on in the United States' Northwest (Figures 1 and 2).

Figure 1. Harvest aid in operation with 2 ground and 2 elevated workers.

It was envisioned that two workers would pick from the ground with conventional picking bags, and deposit their fruit onto a receiving conveyor. An additional two workers would pick from an elevated platform, and deposit their fruit directly onto an upper conveyor. A ladder at the front of the picking platform would allow any worker who had picked all the fruit in his or hers "area" to quickly move and pick at other locations, thereby minimizing unproductive time.

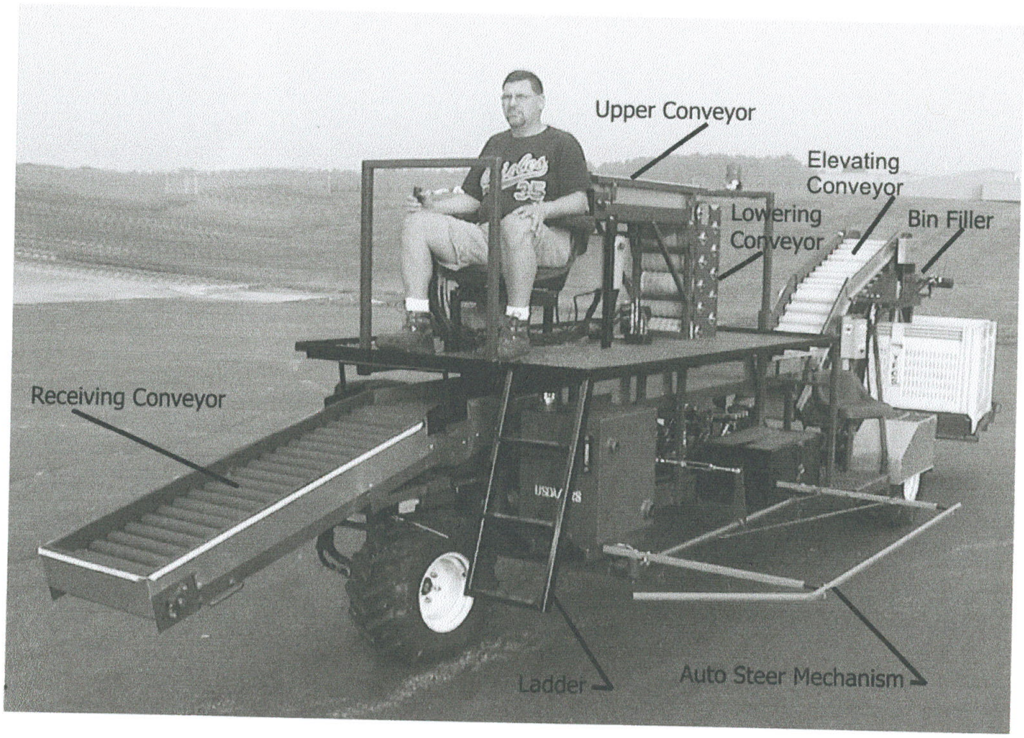

Figure 2. Overview of harvest aid showing main components.

The upper conveyor would transfer the fruit to a lowering conveyor, which would deposit the fruit onto the receiving conveyor (Figure 3). Before the receiving conveyor transferred the fruit to an elevating conveyor, an area was provided for a person to sort out defective fruit (Figure 4). As typical with manual sorting conveyors, the fruit was rotated in this area for better inspection. The elevating conveyor delivered the fruit to the fill conveyor that lower the fruit into a rotating bin. An outlet flap and rotating brush eased the fruit's placement into the bin. An ultrasonic sensor determined the level of fruit in the bin and activated a circuit to incrementally raise the fill conveyor as the bin was filled.

The receiving and upper conveyors were made of 33 mm (1 in.) schedule 40 aluminum pipe covered with 12.7 mm-thick (0.5 in.) pipe insulation (Armstrong World Industries, Lancaster, PA). The pipes were supported by nylon bushings. The nylon bushings were supported on extended pins on 2040 roller chain spaced every 76.2 mm (3 in.). The lengths of the receiving and upper conveyor pipes were 457 mm (18 in.) and 280 mm (11 in.) respectively. The lowering conveyor was composed of 127 mm-dia. x 457 mm-long (5 in.-dia. x 18 in.-long) foam cylinders mounted on 19 mm-dia. (0.75 in.) shafts. Five of these foam cylinders spaced 127 mm-vertically (5 in.) faced another set of similar foam cylinders that were offset 152.4 mm (6 in.) horizontally and 63.5 mm (2.5 in.) vertically. The two sets of foam rollers were rotated in opposite directions to engage and lower fruit. A transfer flap made from 3 mm-thick (0.125 in.) belting covered with 12.7 mm-thick (0.5 in.) Poron (Rogers Corp., East Woodstock, CN) enabled fruit to gently move from the lowering to the receiving conveyor. The elevating conveyor consisted of 27 mm (¾ in.) schedule 40 aluminum pipes covered with 12.7 mm-thick (0.5 in.) pipe insulation. The pipes were 394 mm-long (15.5 in.) and were supported by B-1-1 attachments of 2050 roller chain spaced every 127 mm (5 in.). The pipe insulation was covered with a

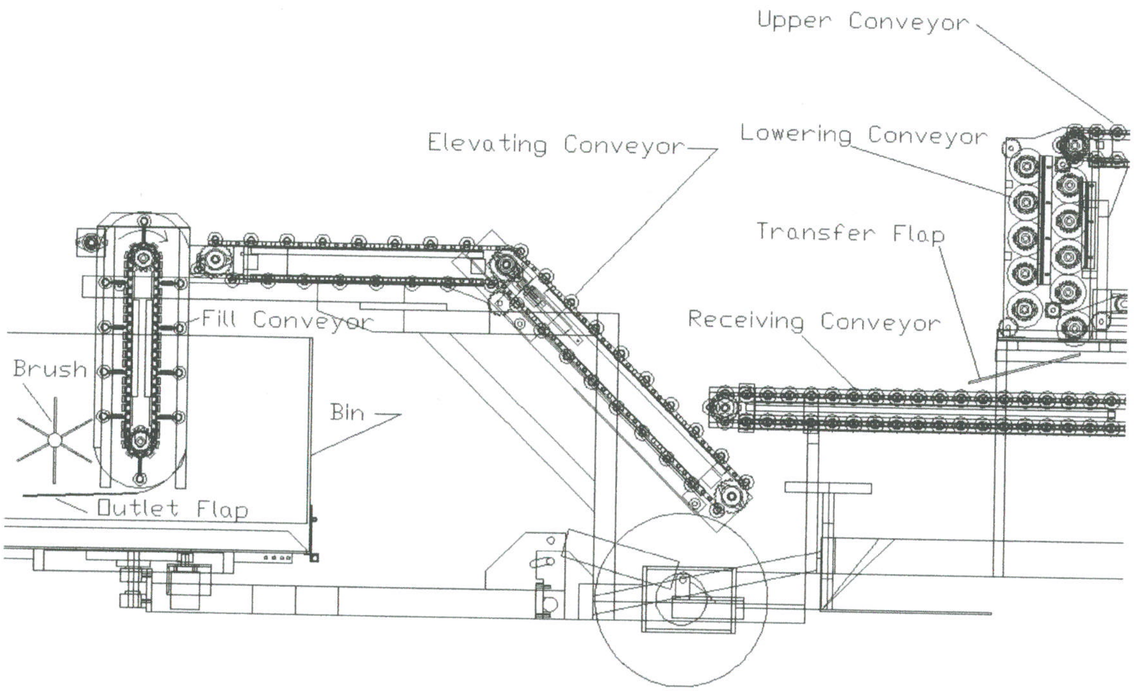

Figure 3. Schematic of fruit handling system.

Figure 4. Fruit sorting section of receiving conveyor.

0.56 mm-thick (0.02 in.) polyurethane-coated nylon fabric that formed pockets to collect and transport the fruit. The design was such that the pockets were stretched at the outlet end of the conveyor to carefully discharge the fruit onto the flights of the fill conveyor. The two conveyors were timed so that the fruit transfer from flight to flight always had the same orientation. The flights on the fill conveyor were made of 27 mm (¾ in.) schedule 40 aluminum pipes covered with 12.7 mm-thick (0.5 in.) pipe insulation. These pipes were space 63 mm (2.5 in.) from and bolted to B-1-1 attachments of 2050 roller chain spaced every 127 mm (5 in.). Intermediate links also had B-1-1 attachments that supported 25.4 mm (1 in.) wide flat panels that were covered with 6.4 mm-thick (0.25 in.) Poron. The flights and these panels combined to support fruits as they were lowered into the bin.

The unit was three-wheeled (front wheel steerable, ± 80°), all-wheel-hydraulic-drive. Power was supplied by a 19 kW (25 hp) engine that drove a 75 L/min. (19.8 gpm) pressure-compensated, variable-volume hydraulic pump. One of the elevated workers used a pilot-control joystick to activate ground speed (forward and backward) and steering to position the unit between rows. When the harvest aid was properly positioned, the worker would engage the automatic circuit. The automatic circuit activated automatic steering and continuous creep ground speed. Autosteer was accomplished by having a four-bar linkage on either side of the unit (Figure 2). When either outside bar engaged a tree, the two parallel supporting bars would rotate and activate a switch that would cause the front wheel to steer away from the contacted tree. When the outside bar lost contact with the tree, a tension spring would return the supporting bars to their initial position and return the switch to it's initial position. The control circuit would then cause the front steerable wheel to return to it's neutral position. The continuous creep ground speed control deactivated the pilot-control joystick and diverted hydraulic fluid through a pressure compensated flow control valve to the ground drive wheel motors. Adjusting the flow control valve set the ground speed. We envisioned that setting the perfect speed to enable efficient picking under varying conditions would be difficult. A pair of three-way switches were added to each end of the upper conveyor. If the pickers were near the rear of the upper conveyor and still had fruit to pick, they could trigger one of the switches to interrupt harvester forward movement. When they caught up and were near the front of the upper conveyor, they could trip the other switch and continue movement of the harvest aid.

Safety Issues

Having the harvest aid in an autonomous mode could present some safety issues. Three emergency "kill" switches were placed throughout the harvester. Engaging anyone of these "kill" switches would disengage all actuators on the harvest aid. There was also concern that when the ground workers emptied their picking bags they could be run over by the front ground wheel. To prevent this, a switch with an extended rod was mounted to each side of the receiving conveyor about 300 mm (12 in.) in front of the front wheel. If the workers got too close to the wheel their body would engage the rod of the switch which would interrupt the forward movement of the picking aid.

Test Procedures

The harvest aid was tested in a block of 'Golden Delicious' with row spacing of 1.2 m x 4 m (4 x 13ft.). Angle of the trellis was 60°. The outer arms for the autosteer were setup with about 200 mm (8 in.) spacing on each side. Four experience picker, but not experienced on the pick aid, conducted the tests. A knowledgeable worker manned the sorting area and the fruit removed was weighed. Four bins were harvested and the time to fill each bin was recorded. The times to change bins were not timed. The fruit in each bin was weighed. After harvest, the cooperating grower and farm manager determined if the harvested fruit had acceptable damage levels compared to conventional hand harvesting. Two of the pickers doing conventional hand harvesting with picking bag and ladder were timed for a day and their harvest rate determined.

Results

The autosteer performed as designed, but encountered problems when the between-row spacing varied more than anticipated. If this spacing was much less than anticipated, both outer arms would be engaged and the system did not know how to respond. If the spacing was much wider than anticipated, the harvest aid would stay to one side and not be centered in the row. This condition would place one upper worker too close to the canopy and one worker too far from the canopy for efficient picking. Testing quickly identified uniformity as an important factor for satisfactory operation of autosteer. The creep speed worked very well and the operators quickly adapted to triggering the switches to control harvest aid movement. All conveying components worked well.

The two workers picking conventionally averaged 7.3 kg/worker-min (16.1 lbs./worker-min). The four pickers on the harvest aid average 12.25 min/bin with standard deviation of 0.73. It seemed that the pickers were working very efficiently and probably could not work a lot faster. It was estimated that in normal operations it would take a minute to change bins. Adding a minute to change bins resulted in pickers averaging 8.9 kg/worker-min (19.6 lbs./worker-min) with the harvest aid, a 22% increase over conventional hand harvesting. As the picking crews become more experienced with the harvest aid, this productivity advantage may even increase. The person sorting the fruit had ample time to observe and remove defective fruit. He removed on average 5% of the harvested fruit. After harvest, the cooperating grower and farm managed determined that the harvested apples had excessive bruises and would be unacceptable for the highest fresh market grade. We conclude that the bruises were inflicted during the bin filling process and that the filler would need refinements or change to a different binfiller with better operating performance.

Conclusion

A mechanical harvest aid was developed for narrow inclined trellises that allowed pickers free movement in order to optimize their picking time. Autosteer and auto-creep features worked well. However the autosteer feature needs uniform between row tree spacing. Stop/start ground movement switches on upper conveyor were very effective and pickers adapted very quickly to them to control harvest aid movement. Field tests demonstrated the potential to improve worker productivity up to 22%. Cull fruit could be removed during the harvesting process. Fruit damage was excessive and will require refinements in the bin filler.

Future Research

It was envisioned that the harvest aid would also be used for pruning and thinning operations. The autosteer and continuous "creep" speed, plus elevating workers should be useful features that will make these operations more efficient.

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